drawer. The lower part of the cord is attached to a cross-bar which unites the bottom of the two rings. When the cord is stretched under the action of the sounding-weight, the upper arm of the lever falls into the prolongation of the cord, in a vertical position, and the lower arm keeps the drawer close. When the action of the sounding-weight ceases, the drawer opens under the action of the antagonistic spring. The process is the same as in the large apparatus, but in a slightly different form, permitting a much smaller and lighter order, which is more suitable to the superposition in series. To avoid the lower apparatus interfering by their additional weight with the opening of the higher ones, when the action of the sounding-weight ceases, each apparatus and the corresponding cord were exactly counterbalanced by a floater of glass in the form of a vial, inclosed in a net and attached to the cord immediately below the apparatus which is wished to be free. Under these conditions the apparatus all open simultaneously, immediately that the sounding-weight touches the bottom, and also close all together at the moment when the cord is drawn up and the sounding-weight begins again to act on them. The simultaneous exposure of several plates at various depths is thus obtained, and it is possible to follow the decreasing action of the light with the depth in one and the same experiment, all circumstances being equal."

The sensitive plates used in these experiments were those of extra rapid gelatine-bromide of M. Lumière, at Lyons. They were protected by a varnish from the action of the sea-water. The duration of the exposure and that of the development were both ten minutes, as in the preceding experiments.

They were carried on in a locality presenting a depth of about 500 metres, so that the purity of the water and the limit of the light were not influenced by the nearness to the bottom. The place chosen was 1300 to 1500 metres from the Cape of Mont Boron, separating the strand of Villefranche from the Gulf of Nice.

Amongst the series of plates obtained the following succeeded well and are particularly instructive.

Series A.—Between 1.15 and 1.25, April 7, 1886, the sun being about 60° above the horizon. The sky was very clear and the sun brilliant; a moderate breeze from the east made little waves.

Plate 1. Exposed at 430 metres: no trace of luminous impression.

Plate 2. Exposed at 390 to 393 metres: a very faint trace, but yet a clear one.

Plate 3. Exposed at 350 metres: a still faint impression.

Plate 4. Exposed at 310 metres: a strong impression.

Plate 5. Exposed at 270 metres: a very strong impression.

Plate 6. Exposed at 230 metres: completely blackened, as were the following.

The limit of light is, then, very exactly towards 400 metres in April, in the middle of the day, in fine weather. This is as complete a confirmation as possible of the conclusion arrived at in the preceding experiments.

Series B.—Between 8.20 and 8.30, April 5, 1886. Sky veiled by a uniform layer of white clouds thick enough for the sun to project no shadow. Moderate breeze from the east.

Plates 1, of 450 metres, and 2, of 415, have no impression.

Plate 3, of 350 metres, presents a very slight impression, a little less strong than that of plate 3 (390 metres) of Series A.

Plate 4, of 315, is of the same force as plate 3 of Series A.

Plate 5, failed by accident.

Plate 6, of 245, and the following, are completely blackened.

Series C.—Between 6.5 and 6.15, April 8. The setting sun was hidden by a bank of black clouds. The rest of the sky was pretty clear, with some little cirro-strati with a faint white light. The light was altogether faint, and like that which is generally found when the sun has just set. The surface of the sea was little agitated, with a slight breeze from the west.

Plates 1, of 400 metres, 2, of 340 metres, and 3, of 300 metres, have no trace of impression.

Plate 4, of 260 metres, is of almost the same force as plate 3 of Series A.

Plate 5, of 220 metres, similar to plate 4 of Series A.

Plate 6, of 180 metres, like plate 5 of Series A.

Plate 7 and the following, completely blackened.

The limit in this last series may be placed with all probability at 290 to 295 metres from the surface.

We see from these experiments that the layers situated at 300 metres are lighted every day, not for a very short time, but all the time that the sun is above the horizon; at 350 metres the light penetrates at least during eight hours daily.

According to the tables that M. Holatschek has drawn up for the latitude of Vienna, especially after the photochemical experiments of MM. Bunsen and Roscoe, the actinic intensity of the light of the blue sky would be on April 21, 33 at 8.30 in the morning; 38·07, at noon; and 14·18 at 6 p.m.; that of the sky and the sun at once would be on an average, in April, 75 at 8.30 a.m., 133 at noon, and 15 at 6 p.m.

According to these figures, the depth that the actinic rays attain in the sea after the setting of the sun is very remarkable. The Commission wait, however, to have more numerous experimental proofs to try to calculate a formula of absorption of which they have to determine the constant for sea-water.

5. *New Experiments on the Effect of the Seasons on the Limit of Penetration of Daylight in the Lake of Geneva.*

The results of these, which require to be confirmed under better conditions, seem to indicate that the difference of transparency between the waters of the lake in winter and in summer is greater than one would have thought. On the other hand, the want of agreement with the experiments of Series 3 leads one to think that the distribution in extent and depth of the layers of troubled water brought by the affluents of the lake is subject to variations difficult to foresee and to appreciate.

The Report concludes by referring to certain improvements in the apparatus.

THE REPORT OF THE KRAKATAŌ COMMITTEE OF THE ROYAL SOCIETY.

PART IV. of this Report, on the optical phenomena, by the Hon. F. A. Rollo Russell and Mr. E. Douglas Archibald, comprises 311 pages of letterpress, or the major portion of the work. Owing to the enormous mass of material which went on accumulating for nearly four years from the date of the eruption, as well as the complexity surrounding the optical phenomena, which in some cases were entirely novel, and in others differed both in quality as well as intensity from their normal analogues, it was plainly a work of some considerable difficulty to decide how best to arrange and discuss the data, as well as to avoid arriving at hasty conclusions from the first indications of appearances which continued in part right up to the beginning of 1887. When the wonderful sunsets appeared in this country, the idea of their being connected with the eruption of Krakataō was first suggested and traced out with remarkable clearness by Mr. J. Norman Lockyer, F.R.S., in his article in the *Times* (December 8, 1883).

From the results of certain experiments by himself, he had concluded that, while under ordinary circumstances aqueous vapour preferentially stops by absorption the more refrangible blue rays, under certain circumstances somewhat analogous to the conditions under which the blue and red solutions of gold were obtained by Faraday, aqueous molecules exist which stop the red rays and transmit the blue. Such so-called "red molecules" were found to be larger than the "blue molecules."

Combining this with the facts which indicated an unusual extension of volcanic dust and vapour into the air by Krakatão, as well as the succession of dates, the occurrence of white suns in the Indian Ocean and blue suns at a distance and at noon, and the initially rapid progress of the coloured suns and twilight glows round the equator, and their gradual spread to the extra-tropics (at first only faintly realized through lack of sufficient data), he constructed the hypothesis that all the optical effects witnessed in England in November and December 1883 were, like those which preceded them, nearer the equator, traceable to the products of the August eruption of Krakatão, carried thither by the upper currents of the atmosphere. Although, in one or two minor details, such as a supposed south-to north line of coloured suns over India, the vastly greater mass of evidence ultimately collected by the Committee enabled them to arrive at a more correct conclusion, yet, in its main features, such as the east-to-west current along the equator, and the concatenation of such at first apparently unconnected phenomena as a sunset in London and a volcanic eruption in Java, the work of the optical section of the Committee has practically resulted in filling in the framework sketched out by Mr. Lockyer. As time progressed, fresh data came pouring in, which not merely testified to the universality of the phenomena over the north and south temperate zones, but helped to fill up the gaps which necessarily occurred over the oceans and near the equator.

In spite of all these links in the chain of circumstantial evidence, many persons still continued to doubt the connection of the extra-tropical twilight glows with the analogous appearances in the tropics. In the case of the blue and green suns, the evidence even at first, was too strong to allow much doubt that they were in some way or other connected with the eruption. Yet even so, the rate at which they travelled (from 70 to 80 miles an hour) along the equator was too much for some persons, whose powers of imagination could hardly grasp the enormous scale on which the operations were conducted; while in the case of the extra-tropics, all sorts of queer and gratuitous hypotheses were put forward to account for what they beheld from their own windows.

Now, a very cursory glance at the general data and evidence, as well as at the maps given in Section III., will, we think, convince the most sceptical that the grand series of optical appearances which were first seen in the neighbourhood of Krakatão on the day of its great eruption, extended themselves, at first rapidly in longitude, and then slowly in latitude, until they finally embraced the whole earth. It will also show that their arrival in Europe was but a mere incident in their spread over a region *fifty times as large*. All this, however, has had to be put forward in detail.

Other points which have had to be described or discussed were—

(1) The proximate cause of the abnormal twilights, and an explanation, as far as was possible, of the way in which they differed from ordinary twilights, both in quality and intensity.

(2) The coloured suns, large corona round the sun and moon, and the sky haze or eruption cloud which evidently caused them.

(3) Then came the geographical distribution, the height and duration of the glows, a list of analogous phenomena on former occasions, opinions put forward to account for the present series, and finally a general analysis of their connection with the eruptions of Krakatão in detail, each of which demanded a separate section.

To give some idea of the principal facts and conclusions of this part of the work, we will commence with the abnormal twilights, considered as local phenomena.

The phases of ordinary twilights have been investigated with much attention by Kepler, Le Mairan, Dr. Hellmann, and Dr. von Bezold,[1] of whom the last discussed them with wonderful clearness in 1863, and showed that certain sequences of colour and intensity take place normally, which have apparently been entirely overlooked until the present series brought the subject again into notice.

Thus the normal sunset consists chiefly of a series of bands of colour parallel to the horizon in the west in the order, from below upwards—red, orange, yellow, green, blue, together with a purplish glow in the east over the earth's shadow, called the "counter-glow." As the earth's shadow moves upwards towards the zenith, and passes invisibly across it, a reddish or purplish glow suddenly appears above the coloured layers in the west, in a spot which previously appeared of a peculiarly bright whitish colour. This purple glow is substantially the "primary glow," or, more definitely, "*erste purpurlicht.*" It is peculiar in appearing *above* the horizontal colours, and in not extending far on either side of a vertical plane through the sun and the spectator. As this glow sinks on the horizon and spreads out laterally, it forms the first red sunset. After its disappearance, under *favourable conditions*, a second edition of twilight colours analogous to the first commences, with a similar bright spot (*dämmerungschein*) out of which a second purple light appears to be suddenly developed, and sinks on to the horizon as the secondary or "after-glow."

These are the normal phases of a complete sunset according to Dr. von Bezold, and the present series only appear to be abnormal in exhibiting certain peculiar yellow and greenish tints, a less-defined boundary of the earth's shadow, together with a much greater brilliancy, extension, and duration of the first, and particularly of the second, purple glows. The horizontal layers were less conspicuous than usual, and the abnormal extension of the purple light made it appear as though there was an inversion of the usual order of tints from below upwards.

In order to explain these and other peculiarities which we have not scope to describe, Mr. Russell starts with the observed fact of a sky haze which, in the tropics, tended to transmit blue or green rays in preference to red, and assuming that all the usual elements which are included under the term "optical diffusion" were present, viz. diffraction, refraction, and reflection, describes what should be the effects (1) assuming a haze composed of opaque particles, and (2) one composed of very thin reflecting plates into which condition a large proportion of the pumice ejected from Krakatão is shown to have been transformed. His conclusion is that the distinctive features of the Krakatão glows were due mainly to reflection from these fine laminæ, of rays already tinted in a certain order, by diffraction through the dust of the haze layer and the lower atmosphere, as well as by the selective absorption which ordinarily takes place in the more humid horizontal layers near the earth's surface. The direct as well as diffuse reflection by the plates and opaque dust, which lay, as Mr. Archibald has shown in Section IV., at a height of from 50,000 to 100,000 feet, of rays tinted in succession as both the direct and reflected twilight boundaries followed the descending sun, and the peculiar transmissive quality of the stratum for the more refrangible rays, appear to afford a reasonable explanation of the peculiar silvery glare, the unusual colouring, and the unusual extension of the purple glows.

It is admitted that diffraction played an important part, as it does in ordinary sunsets (Lommel, for example, attributes all the red tints to this cause); but both in this section and those that follow, many considerations are urged against the view held by Prof. Kiessling that the development of the primary glow is chiefly due to diffraction, while the secondary glow is as confidently asserted to be due to reflection. One of the principal objections to the reflection hypothesis in explanation of both the ordinary as well as the present extraordinary development of the purple glow, is its limitation at first to a narrow band, a fact which cannot be explained by absorption, and which is equally at variance with Fresnel's law of reflection from small globular dust, which would be equal in all directions. On the lamina, and particularly the vitreous lamina assumption, however, it is intelligible, since the maximum reflection would then be like that from the sea, in the vertical plane through the sun and the eye.

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[1] *Pogg. Ann.*, Bd. cxxiii. (1863), pp. 240–76.

Moreover, the richly coloured and prolonged secondary glows, which were the most characteristic feature of the Krakatão twilights, are shown by Mr. Archibald, in Section IV., when dealing with their secular duration, to have reached a distinct minimum when the large diffraction corona round the sun, from Prof. Riccò's observations,[1] appeared at its greatest brilliancy; while the curve of their duration on Plate XXXIX., representing Dr. Riggenbach and Mr. Clark's observations, shows that they never again reached the same brilliancy or duration as in the two or three months immediately succeeding their first appearance in Europe. Both these facts aid the conclusion arrived at by Mr. Russell, and indorsed by Prof. Kiessling, that they were reflections by the haze stratum of the primary glows. But if these were reflections, the question naturally arises, why not the primary also? and until more effective arguments are brought against this view, as well as Prof. Riccò's objections to Prof. Kiessling's theory of diffraction alone, which are detailed in Section I. (*c.*), p. 250, Mr. Russell's view of the origin of both glows seems to be the more probable as well as reasonable of the two. The haze stratum appears to have been capable of exerting two influences: one, diffraction of the sun's rays by its smallest particles, which, with the absorption and diffraction usually effected by the dust and vapour present in the lower atmosphere, caused the horizontal tinted layers; the other, reflection by its larger particles or laminæ of the horizontal layers, particularly of the lowest red one, when the earth's shadow had arrived at about 25° above the western horizon, and into a position whence the maximum reflective effect could be seen unmasked by a diffusely illuminated background.

The question of the blue and green coloration of the sun is next discussed by Mr. Archibald, particularly with reference to its intrinsic characteristics and physical origin. In Section VII., in which the distribution of the twilight glows and the blue suns on their first circuit of the globe is compared, it is shown that the mean limit of the band of coloured suns was about 11° north and south of the latitude of Krakatão right round the equator, while that of the glows lay 5 beyond this on either side. Along the latitude of Krakatão the colours were mostly white or silvery, and in one or two cases coppery. The colours thus evidently depended on the density of the stream, the glows appearing on its borders or fringes where it was less dense. A similar relation to density appears from a study of the diurnal changes with varying solar altitude, the sun appearing to change from blue near the zenith, through green, to yellow, or disappearance on the horizon. No direct physical explanation of such a phenomenon appears forthcoming, since, according to the physical laws enunciated by Lord Rayleigh and Prof. Stokes, the diffraction of light by particles of the same order of magnitude as a wave-length tends to sift out the shorter blue, and preserve the longer red waves of light. Repeated reflections by small particles tend to the same result.

The explanation proposed by Mr. Norman Lockyer in his article in the *Times* attributed the blue colour of the sun to differences in absorbing power of particles of different sizes, the larger particles being supposed to transmit more of the rays near the red end of the spectrum and the smaller those of shorter wave-length. The difference of size has been shown by Prof. Kiessling to be inoperative so far as scattering is concerned, since for particles whose magnitude is of the same order as that of a wave-length of light, the only case to which Prof. Stokes's law applies, the intensity of the scattered blue rays will be always sixteen times that of the red rays. It can therefore only be explained as an effect of absorption, due to some particular absorptive property of the materials which composed the haze. The phenomenon of a blue or green sun has been observed under natural conditions, many of which are quoted, and in most cases where the air was filled with fine dust from a great variety of sources. It has also been artificially reproduced by Prof. Kiessling with dust-filled air and vapour of water, and particularly of sulphur. Several accounts are given in Section V. of blue suns seen in connection with former eruptions, and Mr. Whymper's observation during an eruption of Cotopaxi is conclusive as to the ability of the finest volcanic ejecta to cause such an appearance. The problem which still awaits solution is, What was the precise nature of the particles or gases which produced the absorption? It seems probable that they were metallic sulphides.

Mr. Archibald next deals with the sky haze and its peculiar effects, more particularly on astronomical definition. Here again it seems to have possessed a selective absorption of the red rays, for in two separate lunar eclipses, 1884 and 1885, the usual coppery tint of the moon was conspicuously absent. He then passes on to the peculiar large corona round the sun and moon, which was first observed by Mr. Bishop at Honolulu on September 5, and which, though less striking than the twilight glows, was, if anything, more uncommon, more constant, and more prolonged in duration. It was a true diffraction corona with a reddish border, and of almost exactly the same size as the ordinary ice-halo, viz. 45° in diameter. It lasted from September 5, 1883, up to October 15, 1886, since which date it has entirely disappeared. Its diameter has afforded an approximate determination of the mean radius of the smaller dust-particles composing the haze, which Mr. Archibald calculates to be 0·00006 of an inch. Its connection with, and independence of, the glows is discussed at length, but we have not space to refer to it.

In Section II., Mr. Russell gives a list of the first appearances of all the optical phenomena from the beginning of 1883 to the end of 1884, from which date the local duration of the glows is carried on by Mr. Archibald in Section IV. up to the end of 1885.

In Section III., Mr. Russell works out the geographical distribution of the optical phenomena, including blue suns and glows, up to the end of 1883, by which time they had virtually covered the whole earth. The general conclusion is, that the phenomena all propagated themselves (with the exception of a narrow offshoot towards Japan) at first due west from Java, at a rate of about 76 miles an hour right round the earth parallel to the equator, and in a band symmetrically disposed for 16° on either side of the latitude through Krakatão. A second circuit with wider limits, 30° north and south of Krakatão, was traced at the same rate, after which the motion became indistinguishable. They then gradually spread in latitude, and ultimately the haze which caused them appears to have invaded our latitudes, like the anti-trade, from south-west to north-east. These circumstances may be best realized from a survey of Mr. Russell's maps, especially that showing the successive limits of the appearances for the first nine days succeeding the eruption.

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[1] Section I. (*c.*), p. 241.

When Mr. Lockyer first pointed out his lines of coloured suns converging towards Krakatão, the data were too scanty for him to recognize that the apparent line through Ceylon, Ongole, and Madras, was due to a widening of the main east to west stream after its first circuit of the globe. As far as the motion of this stream was indicated by African and South American observations, he was perfectly correct, though nothing was previously known as to its velocity or even actual existence. The march of the optical phenomena which is shown in Mr. Russell's maps is indeed the only direct evidence we have of the fact that at 100,000 feet above the earth in the immediate vicinity of the equator, the air in August, and probably, as Mr. Archibald shows, at other times, moves in a rapid and constant current from east to west. Both in Section III. (*b*) and Section VII. he discusses this question in detail, and shows its agreement with the theory of the general circulation of the atmosphere, as well as the motions of the upper clouds as far as they have been observed.

In Section IV., Mr. Archibald investigates the height of the stratum, from observations in all parts of the world where the durations of the primary or secondary glow have been recorded with any attempt at accuracy. Proceeding on the hypothesis that the primary glow was a first reflection of the sun's rays by the stratum, and the secondary a reflection of the primary glow, for which ample evidence is adduced, he concludes that the height of the upper or middle part of the stratum above the earth, diminished from 121,000 feet in August 1883, to 64,000 in January 1884, the lower limits being practically indeterminate. Also, since from Dr. Riggenbach's and Mr. Clark's observations, the glows continued less brilliantly and less prolonged after the first few months right up to the end of 1885, while a decided minimum in the duration, and therefore presumably the height of the reflecting layer, was reached in April 1884; the important conclusion is arrived at, that by that date the larger and more effectively reflecting particles had descended to a lower level, leaving the finest particles suspended at nearly the same elevation as at first. This is further corroborated by the remarkable fact that the large corona reached its maximum intensity during the same month.

In Section V., Mr. Russell gives an interesting list of former eruptions and accompanying atmospheric effects, similar in many respects to those under discussion. During 1783 and 1831, the dates of the famous eruptions of Skaptar Jökull and Graham's Island, &c., and the two years of perhaps the greatest eruptive activity antecedent to that of Krakatão, the *after-glows* and other optical effects were most conspicuous, and from an examination of other eruptions and sequelæ, the general correspondence between the two phenomena seems fairly proven.

Section VI. is a *résumé* of opinions collected by Mr. Archibald, against and in favour of the volcanic origin of the phenomena. Besides its value in exhibiting every aspect of the question, it affords a curious illustration of the narrowness and breadth of human imagination, especially when dealing with phenomena whose universality and minor details were at first only partially realized.

Finally, in Section VII., Mr. Archibald gives a general analysis of the connection between all the optical phenomena and the eruptions of Krakatão both in May and August, in which the various objections on the ground of the initially rapid transmission of the appearances, insufficiency of fine solid ejecta, length of time of its suspension, and the occurence of *apparently* similar phenomena on dates previous to the great August eruption are discussed in turn. The time of suspension of the finest dust in particular, is shown—by an application of Prof. Stokes's formula,[1] $V = \frac{2g}{9\mu'}\left(\frac{\sigma}{\rho} - 1\right)a^2$, for the velocity of a small particle descending in air, and in which viscosity is properly considered—to be *over two years* between 50,000 and 100,000 feet, even assuming the particles to be spherical, which is the most unfavourable supposition. If, as is most probable, they were thin plates, the time would be much longer. A final summary is then given of the direct and local connection between the optical phenomena and the eruptions both of May and August, which the subsequent discovery of the relative though minor importance of the May eruption rendered necessary.

In Part V., Mr. Whipple discusses the somewhat sparse data which show that a magnetic disturbance was generated by Krakatão and travelled round the world at a rate varying from 760 to 900 miles per hour, but the data are too uncertain to allow any definite conclusions to be drawn.

We cannot conclude without drawing attention to the fact that the study of the Krakatão sequelæ has not merely enlarged our conceptions of volcanic powers and the continuity of atmospheric circulation, as well as yielded positive information of great value to different branches of science, but has opened up fresh problems in optical and meteorological physics, the attack and solution of which will stimulate research as well as materially advance the boundaries of our present knowledge of these subjects.

SCIENCE AND THE REPORT OF THE EDUCATION COMMISSION.

THE Final Report of the Commissioners on the Elementary Education Acts, which has excited so much attention of late, deserves to be noticed from a point of view other than any that has yet been taken—that is, the attitude of the Commission towards the teaching of science in elementary schools. In a rather lengthy chapter on "Manual and Technical Instruction," the ground taken by the Commissioners is very clear. The teaching of science in our elementary schools, they say, is yet in its infancy. The importance of science teaching has been so far recognized that simple object-lessons are obligatory in all infant schools. This is a mode of teaching which the Report recommends to be extended. Thus in agricultural districts arrangements could be made for giving practical instruction of the simplest character in the principles of agriculture, the growth and food of plants, and their diseases; and similar instruction in the elements of dairy work might be given to the girls in these districts. The point here laid stress on is one that everybody who knows anything of former attempts to teach science to the children in Board-schools will feel the need of. Science, the Commissioners emphatically say, can never be taught to children out of books alone. No doubt much useful and entertaining knowledge is taken from text-books on science by children; but, to use the words of the Report, the true learning of science cannot be said to begin till the learners are taught to use their own senses in the study, and to rest their acceptance of scientific truth, even the most elementary, not on what they are told, but on evidence supplied by their own observation. To show the curious system of instruction pursued in our schools, it is worth while mentioning that though those simple object-lessons which lie, we are told, at the foundation of scientific instruction are compulsory in infant schools, yet immediately the child leaves the infant school they are discontinued until he reaches Standard V., after which, if he ever gets any scientific teaching, it is out of books alone. One witness considered it ridiculous that English is compulsory and elementary science optional, for, he said, English includes grammar and recitation for boys, the latter of which, he thinks, is far less likely to be useful in a manufacturing district than

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[1] Where σ, ρ, are the densities of the particle and the fluid respectively, a the radius of the particle (supposed spherical), and μ' the index of friction $= \frac{\mu}{\rho}$, where μ is the coefficient of viscosity. Its value is either $(0{\cdot}116)^2$ or $(0{\cdot}14)^2$.